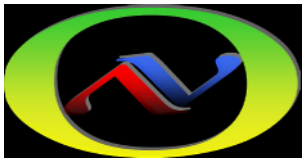
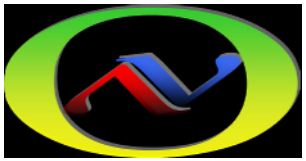


IU/IUCF Strawman APD Packaging for NOνA

C.Bower, W.Fox, S.Mufson, K.Solberg, J.Urheim, G.Visser
Indiana University
January 30, 2005

Background for this talk

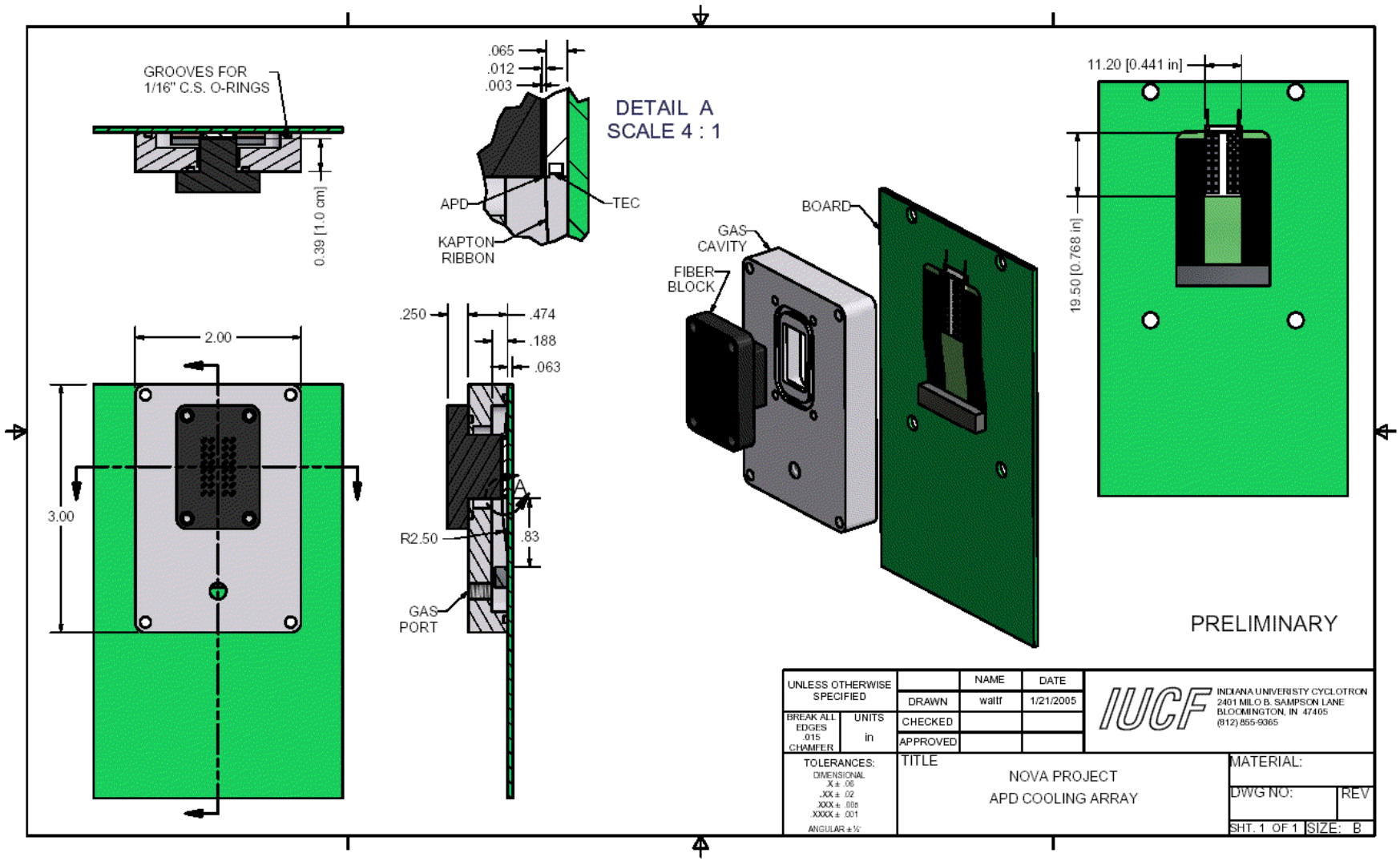


- *APD + readout electronics have special requirements:*
  - optical, thermal, mechanical & electronic couplings needed!
  - the bare die APD array is a delicate system!
  - we have to make *O*(10k) of these: reliability, simplicity, cost!

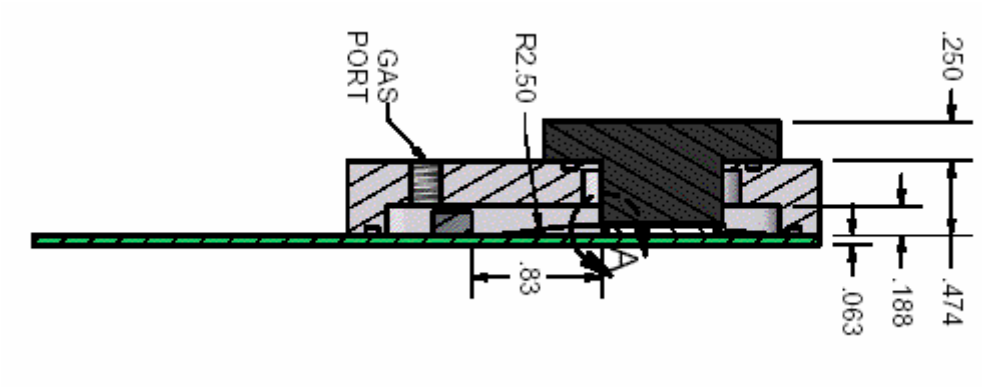
- *We wanted to look into some of the design/fabrication issues*
  - IU group has relevant experience w/ optical coupling issues w/ MINOS
  - availability of engineering expertise at IU Cyclotron Facility.
    → met w/ G. Visser (elec. eng.), K. Solberg (sr. tech.), W. Fox (eng.)

- *IUCF strawman design presented to Stuart, Chuck, JU on 1/21/05.*
  - Driving consideration: thermally isolate APD from PC board
  - Do this by:
    - mount (hot side of) TE cooler on PC board
    - mount APD on (cold side of) TE cooler
    - use kapton ribbon flex circuit to bring electrical connections down to PC brd
      (so actually APD sits on flex circuit which sits on TE cooler)
    - enclose APD/Flex/TE assembly in small gas volume via inj. molded housing
      → optical connector plugs in to this, ~100 micron air gap to APD.

Strawman APD Package



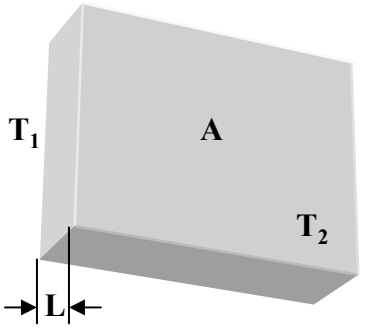
Strawman APD Package



Heat Balance Calculations

Basic Equation

$$Q = k(A/L)(T_2 - T_1)$$



T_1, T_2 = front side, backside temperatures
A = slab area
L = slab thickness

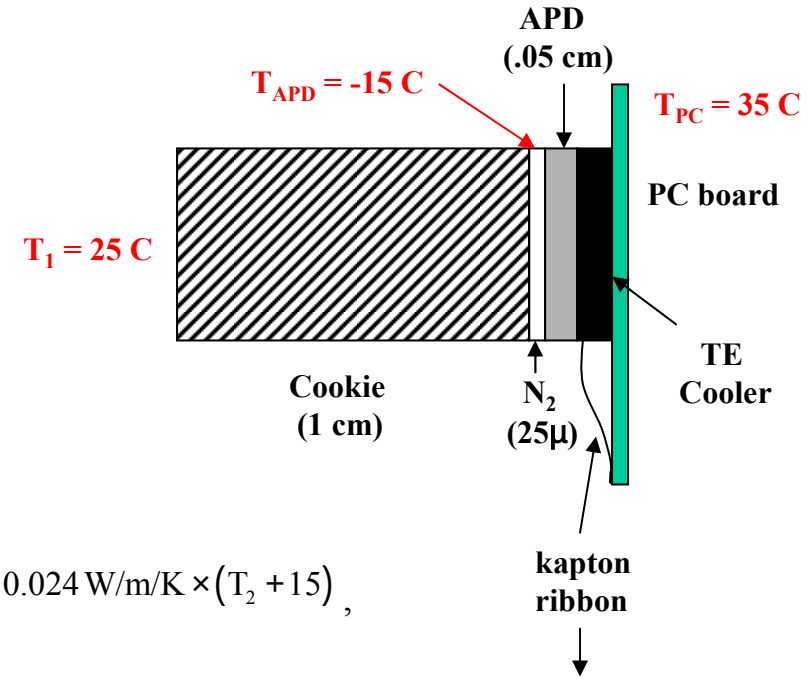
Material Properties: k(W/m/K)

- ABS optical fiber block: k = 0.188-0.334 W/m/K @ 25C
- dry nitrogen: k = 0.024 W/m/K
- ceramic APD packaging, assume Alumina: k = 25-30 W/m/K @ 300K
- kapton: k = 0.155 W/m/K @ 23C
- Cu: k = 400 W/m/K @ 300K

Heat Balance Calculations

Assume area of heat transfer is constant through stack and is equal to area of APD array (A = 19.5mm x 11.2 mm = 2.18 x 10^{-4} m)

Assume heat transfer constant thru stack



1. heat transfer thru cookie/N_2 gas layer:

$$Q(\text{cookie}) = Q(N_2)$$

$$\left(\frac{2.18\times10^{-4}\ \text{m}^2}{10^{-2}\ \text{m}}\right)\times 0.33\ \text{W/m/K}\times(25\text{-}T_2) = \left(\frac{2.18\times10^{-4}\ \text{m}^2}{25\times10^{-6}\ \text{m}}\right)\times 0.024\ \text{W/m/K}\times(T_2+15),$$

where T_2 = -13.7 C is the temperature at the cookie/N_2 layer interface

$$\Rightarrow \textit{Q(cookie)} = \textit{Q}(N_2) = 0.28\ \textit{W}$$

length = 1″ = 2.54x10^{-2} m
width = 0.75″ = 1.91x10^{-2} m
thickness = 0.001″ = 2.54x10^{-5} m

Heat Balance Calculations

2. temperature drop across APD:

$$Q(\text{APD}) = Q(\text{N}_2) = 0.28\,\text{W} = \left(\frac{2.18\times10^{-4}\,\text{m}^2}{5\times10^{-4}\,\text{m}}\right)\times 25\,\text{W/m/K}\times\left(-15-\text{T}_3\right)$$

where **T_3 = -15.03 C** is the temperature at the back side of the APD

3. heat load at back of APD thru kapton ribbon and conductor from PC board (T_{PC} = 35 C):

   a. along kapton

$$Q(\text{kapton}) = \left(\frac{4.85\times10^{-7}\,\text{m}^2}{2.54\times10^{-2}\,\text{m}}\right)\times 0.155\,\text{W/m/K}\times\left(35+15.03\right)$$
$$= 1.5\times10^{-4}\,\text{W}$$

Heat Balance Calculations

a. along conductor:

assume conductor on ribbon has 36 leads, 17μ x 180μ

$$Q(\text{Cu conductor}) = \left(\frac{36 \times 3.1 \times 10^{-9}\ \text{m}^2}{2.54 \times 10^{-2}\ \text{m}}\right) \times 400\ \text{W/m/K} \times (35 + 15.03)$$
$$= 8.8 \times 10^{-2}\ \text{W}$$

4. heat thru kapton to cold surface of TE cooler:

$$Q(\text{total}) = Q(\text{APD}) + Q(\text{kapton}) + Q(\text{conductor})$$
$$= 0.368\ \text{W}$$

The temperature of the cold side of the TE cooler, T_{cold}

$$0.368\ \text{W} = \left(\frac{2.18 \times 10^{-4}\ \text{m}^2}{2.54 \times 10^{-5}\ \text{m}}\right) \times 0.155\ \text{W/m/K} \times (-15.03 - T_{cold})$$

$\Rightarrow \quad T_{cold} = -15.3\text{C}$

So TE cooler must remove 0.37 W with T_{cold} = -15.3 C, ΔT = (35 + 15.3) ≈ 50 C

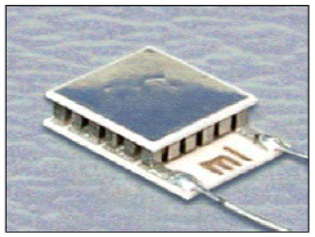
TE Cooler Performance

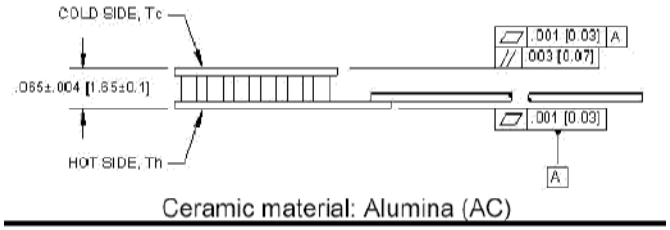
Typical load conditions for unoptimized TE cooler,

$$V\,I = 1A \times 1.5V = 1.5W$$

marlow industries inc.®

Thermoelectric Cooler SP5162

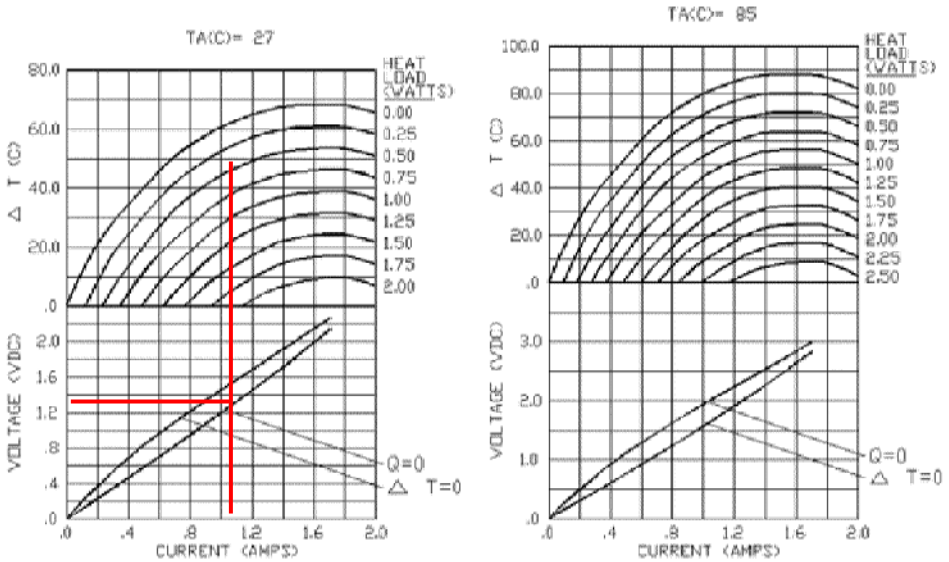




Ceramic material: Alumina (AC)

Performance Curves

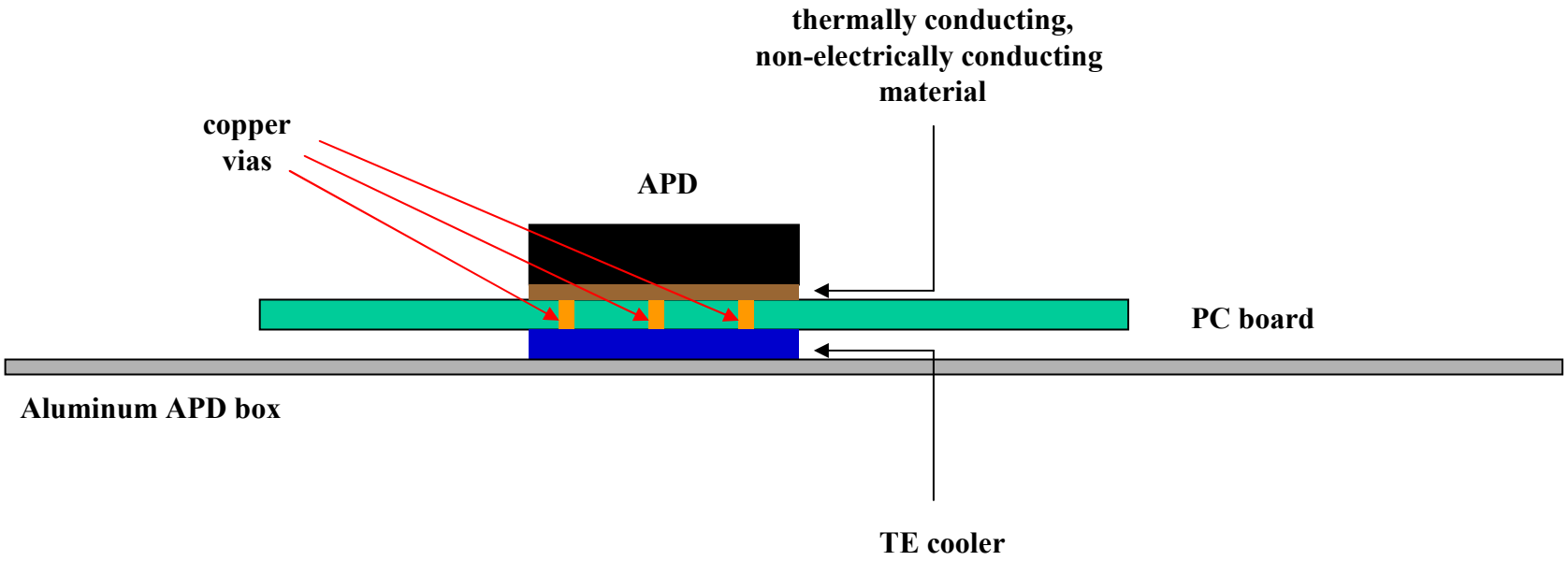
Environment: One atmosphere dry nitrogen



For performance information in a vacuum or with hot side temperatures other than 27°C or 85°C, consult one of our Applications Engineers.

Heat dissipation

Board must dissipate 1.9 W @ 35 C. How to do this? One suggestion



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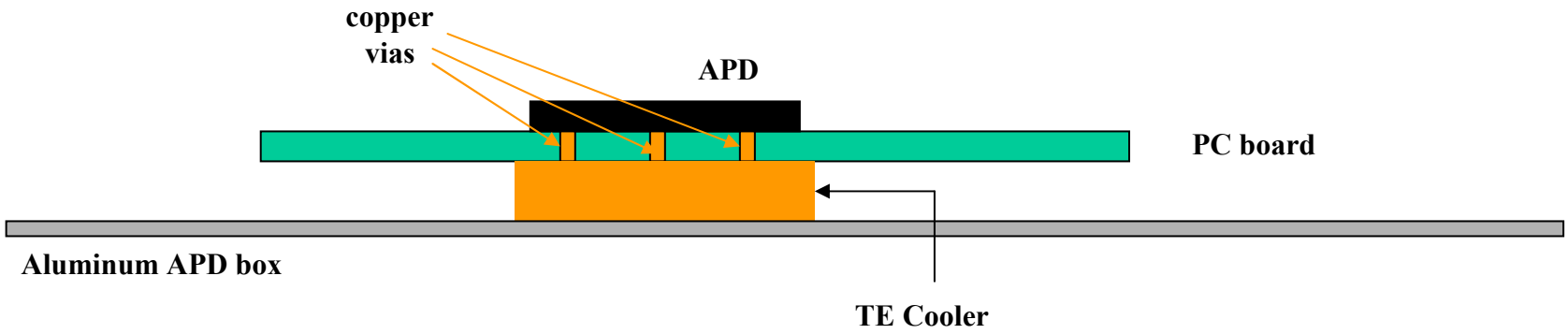
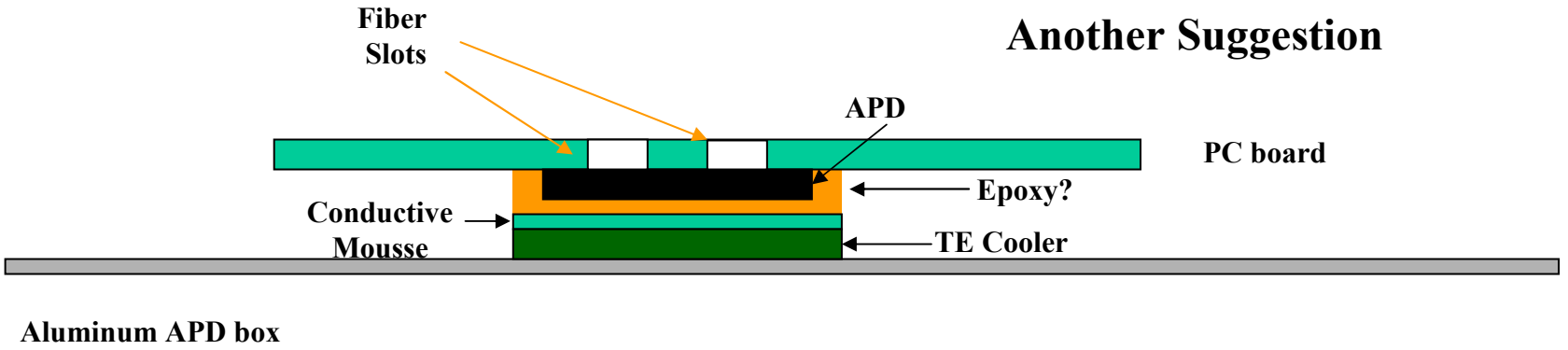
Another Suggestion